AC-LGAD novel geometries exploration by etching of metal on the surface AC-coupled pads

38° RD50 Workshop

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on behalf of the SCIPP UCSC group

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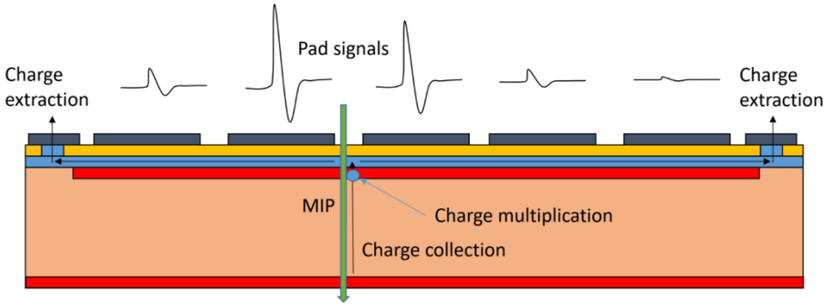
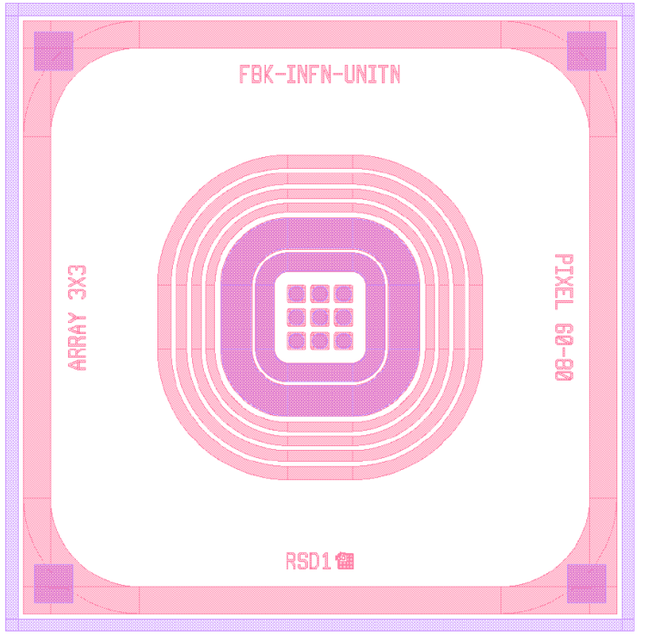
FBK RSD1 etching and testing

FBK AC-LGADs

- AC-LGADs (or RSD) can provide spatial resolution of <10 μm with sparse readout
  - Using information from charge sharing between AC-pads
- Sensors produced by FBK (Italy) with square pad of several pitch and pad size: FBK RSD1 production

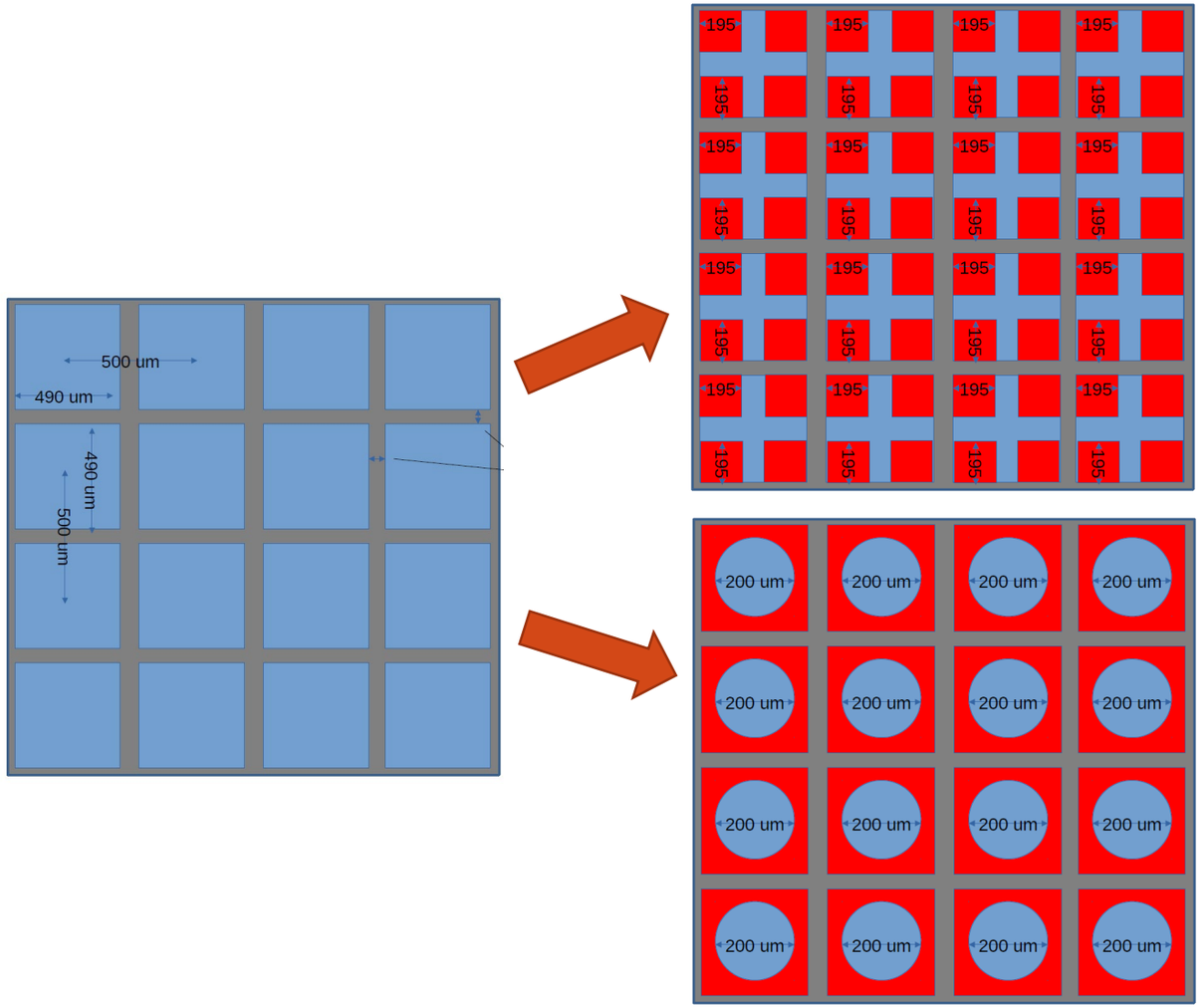


- Alternative pad configuration the metal layer of the pads was etched to create new geometries such as circles, crosses and micro-strips
  - Pad metal surface was defined at BNL (US) with laser-writer lithography
- The alternative geometries have been studied using a focused IR-Laser scans directed both at the read-out side on the front and the bias side on the back of the sensor



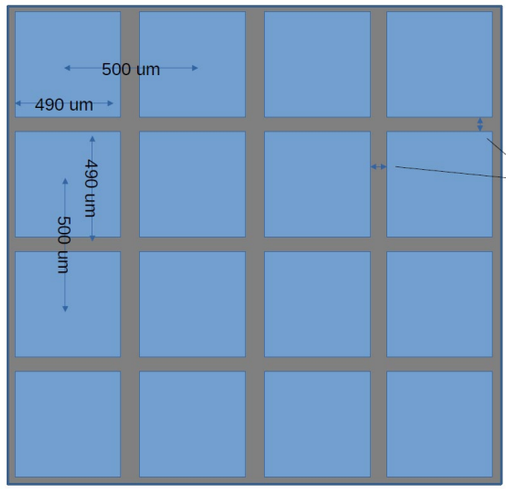
FBK RSD1 etching for novel geometries

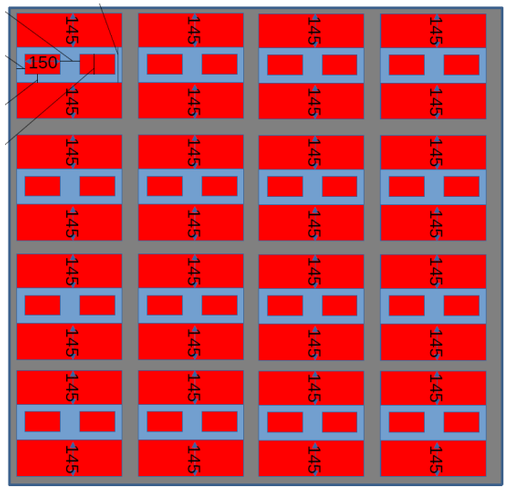
- Etch front metal to produce new AC-LGAD geometries
  - Starting point FBK RSD1 500-490 µm 4x4 pads
  - Sensor also etched on the back to allow back laser illumination
- **Crosses**
  - Reduce pad capacitance
  - Maximize non-metalize area for event reconstruction
  - Expect full signal containment within a "box" for reconstruction
  - Separation in "boxes" were reconstruction is made with 4 channels
- **Circles**
  - Easier to model with analytic formula

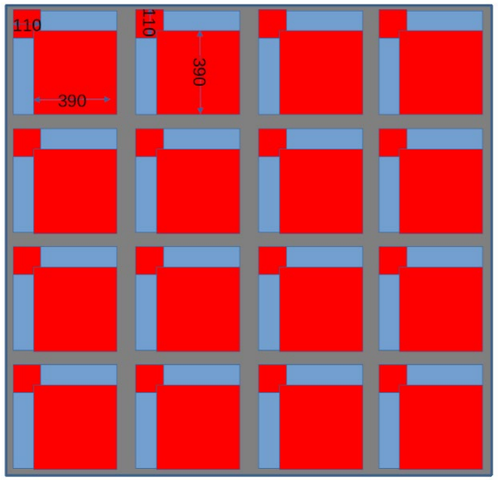


FBK RSD1 etching for novel geometries

- **Open microstrips**
  - Reduce pad capacitance
  - Provide bonding pad in the center
  - Expect better position resolution across the strips than along the strips
- **Microstrip forming boxes**
  - Separation in "boxes" were reconstruction is contained with 4 channels
  - Signal containment in the box
  - Reconstruction with simple ratio X/Y (on ASIC level?)
- **Small pads with large distance**
  - 400um pitch, 100um pad size







FBK RSD1 etching procedure (BNL)

- Chip is mounted on a 2" wafer, and held in place with resist.
- After resist spinning, the pattern is transferred to the chip by laser-writer lithography
- After development, a first etching is by RIE

  to remove the passivation over the aluminum pads
- The aluminum is now exposed and can be etched away

  with standard aluminum etch (or HF)

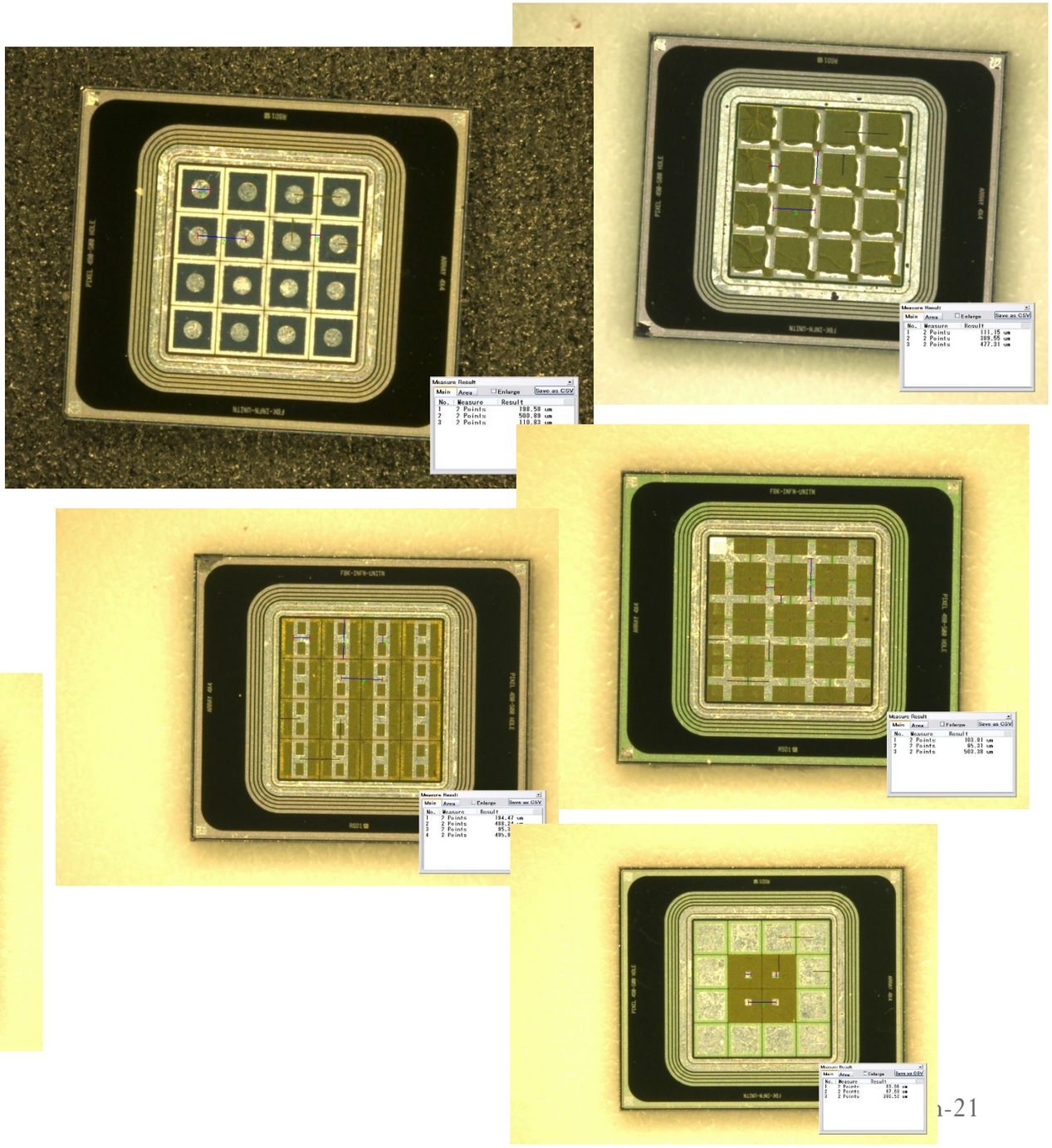
- A dip in resist stripper and acetone cleans the chip

  and separates it from the 2" wafer support

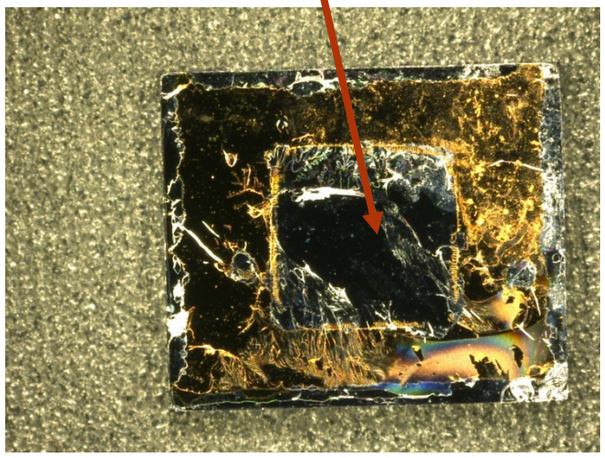
Very time-consuming procedure !!!!!

FBK RSD1 etched

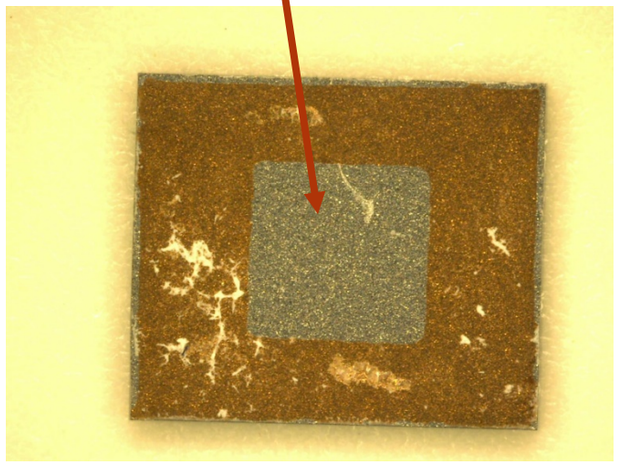
- Procedure quite successful in creating new metal patterns
- Back etching needs some tuning



Damaged backside

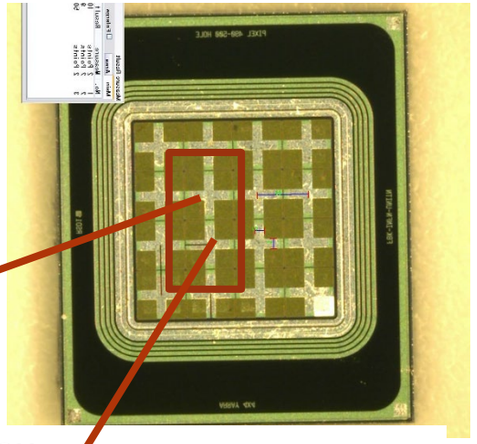


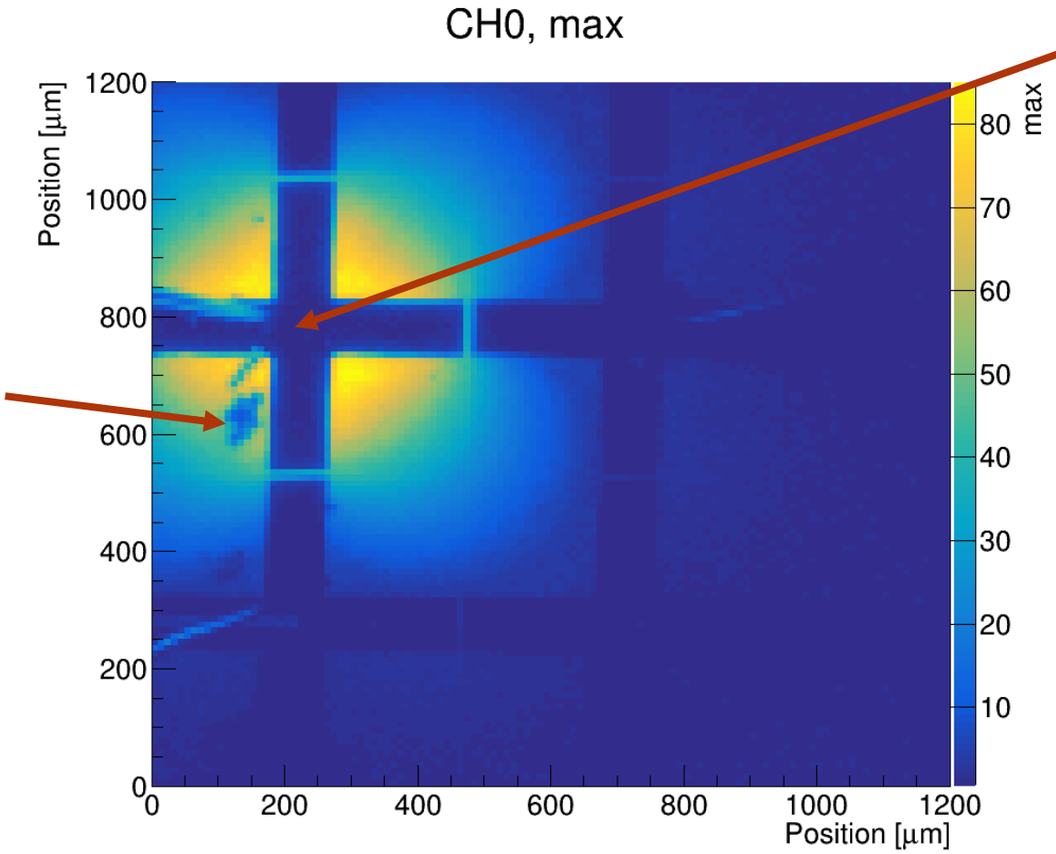
Rough polysilicon texture



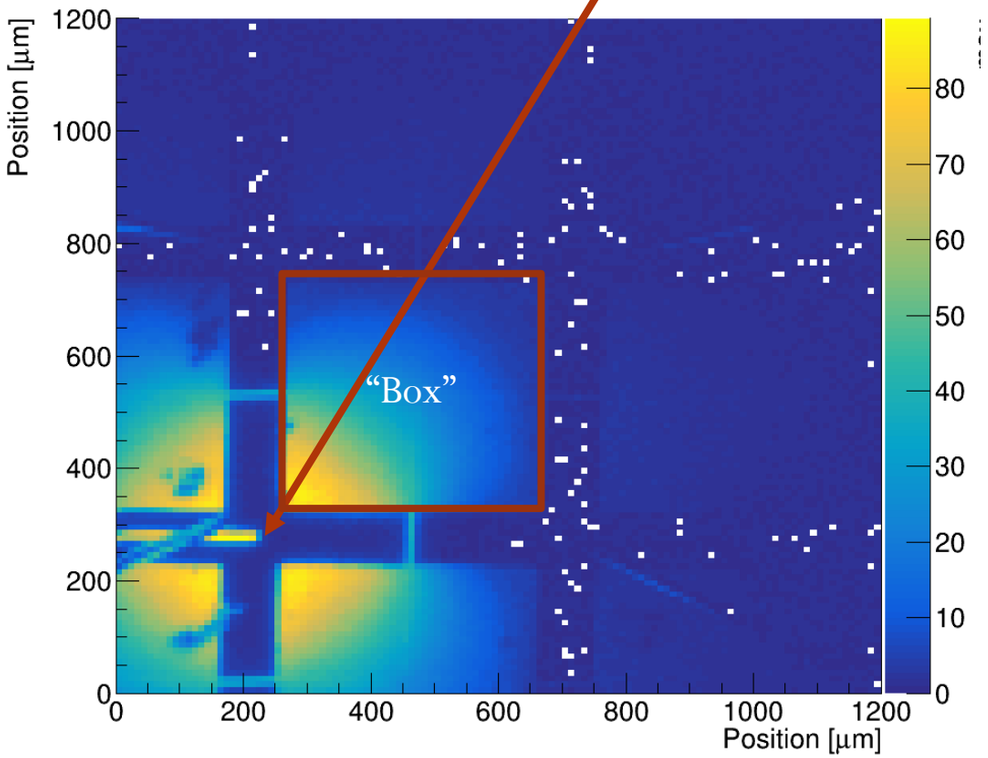
FBK RSD1 etched preliminary results

- Sensor mounted on FNAL 16ch and tested with IR laser TCT
- Crosses design tested (for now): Pmax vs position
- Crosses are 100um wide on the arms

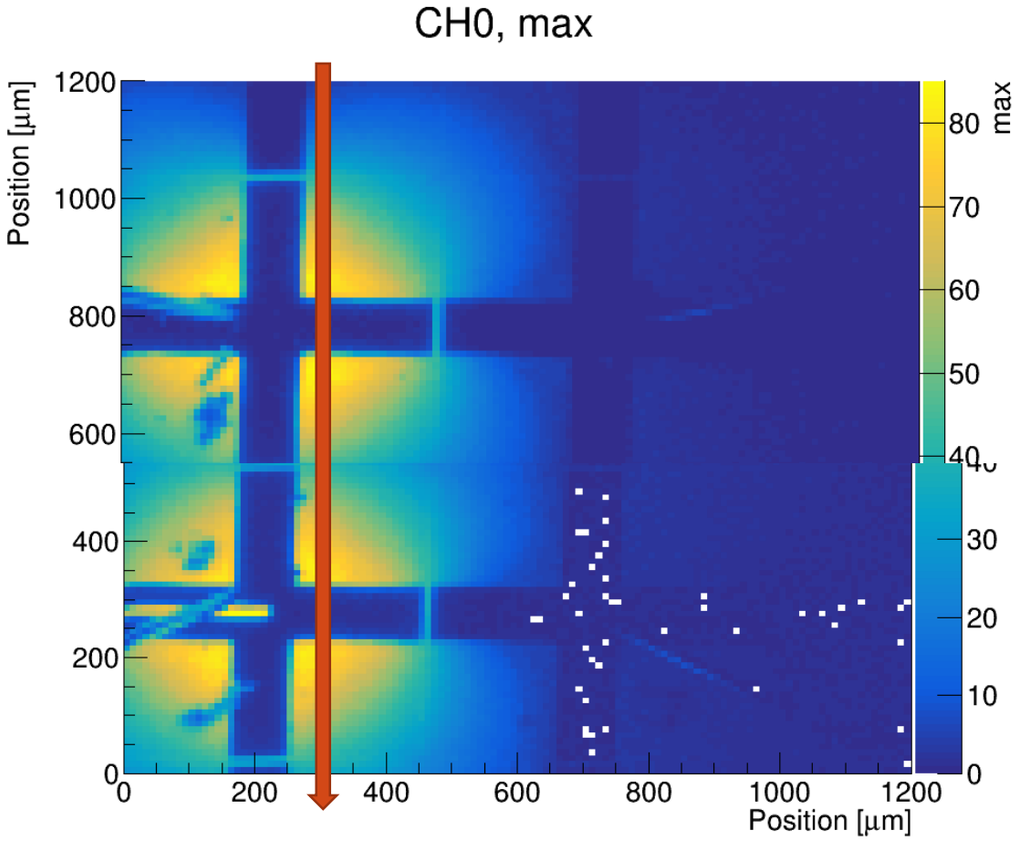


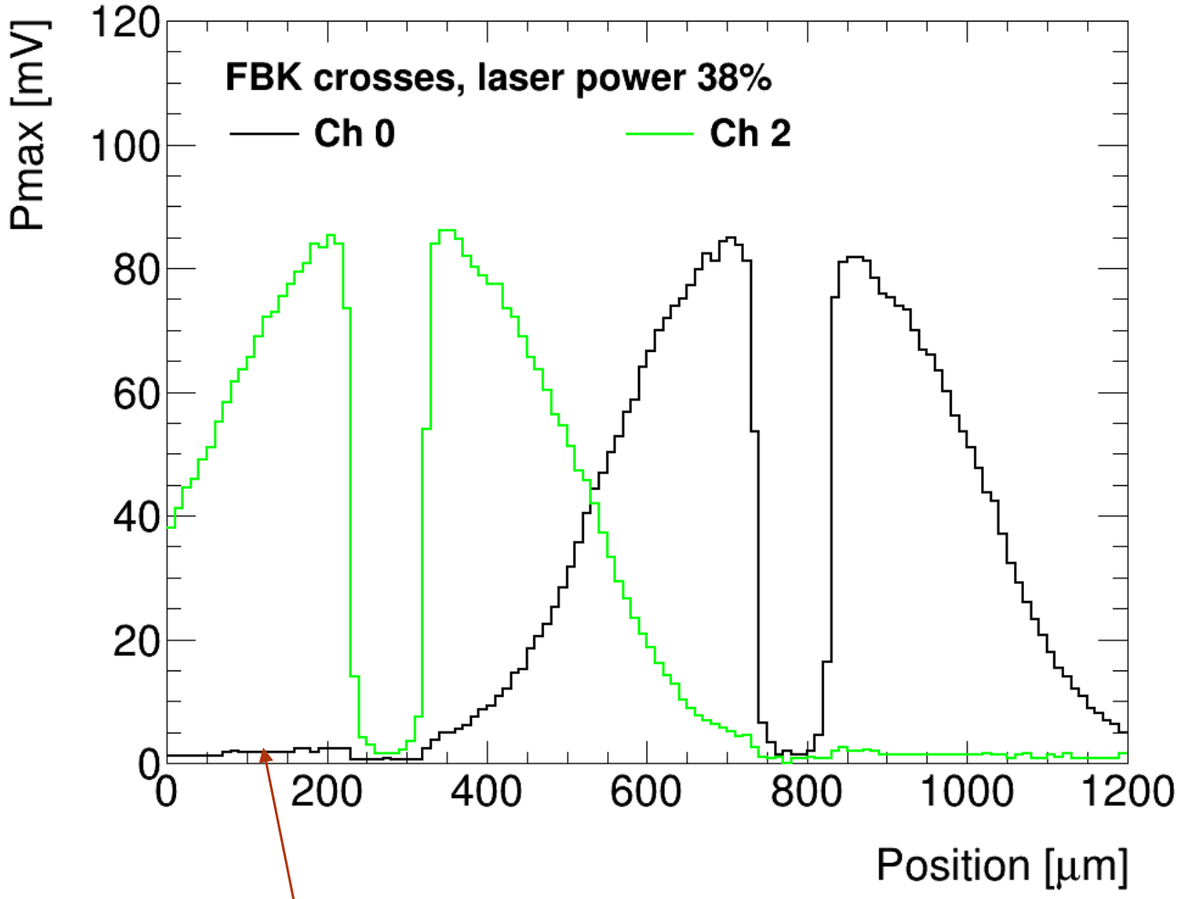


Some residues remain



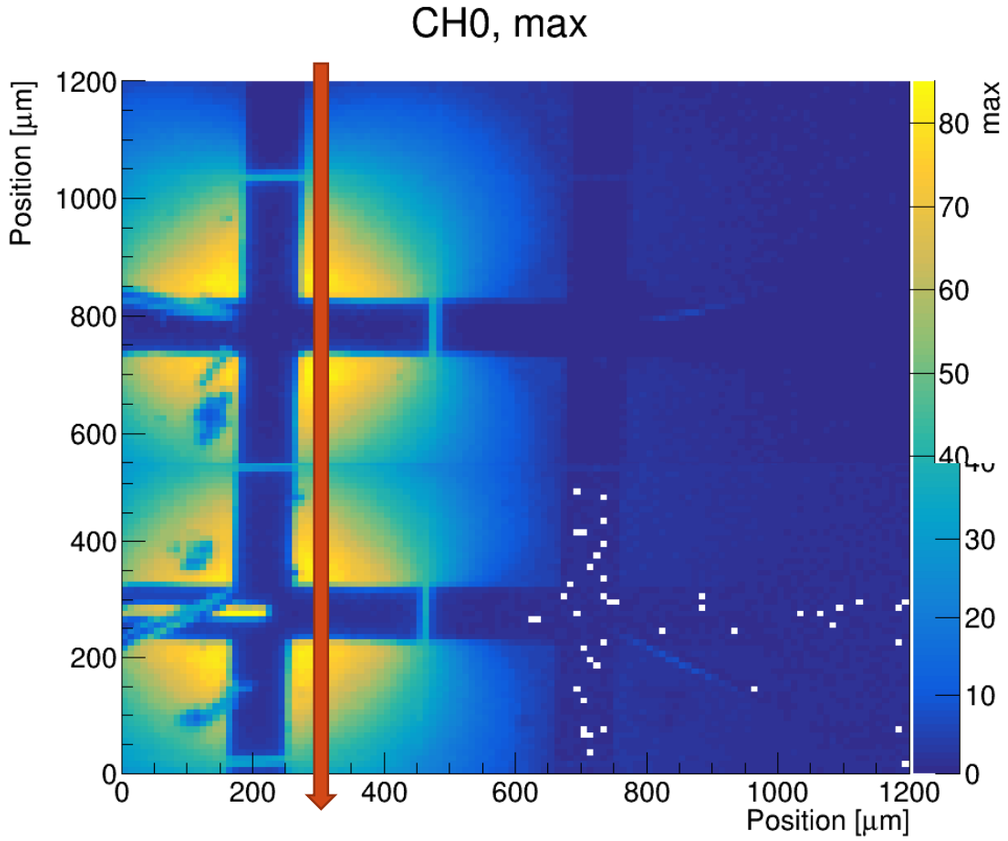
FBK RSD1 etched preliminary results (1D Pmax profile)

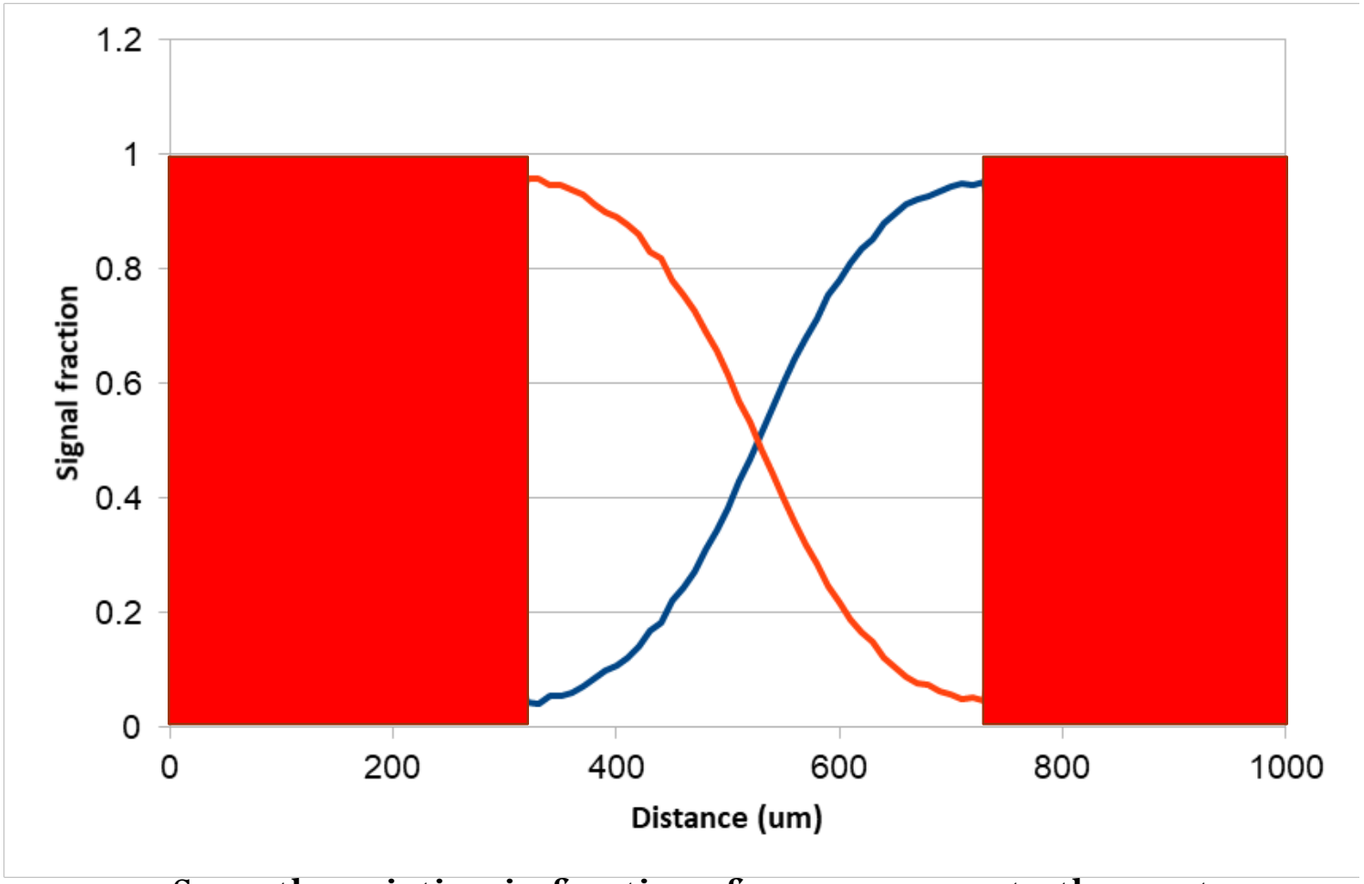




Signal almost fully contained within the box
Few % signal afterwards

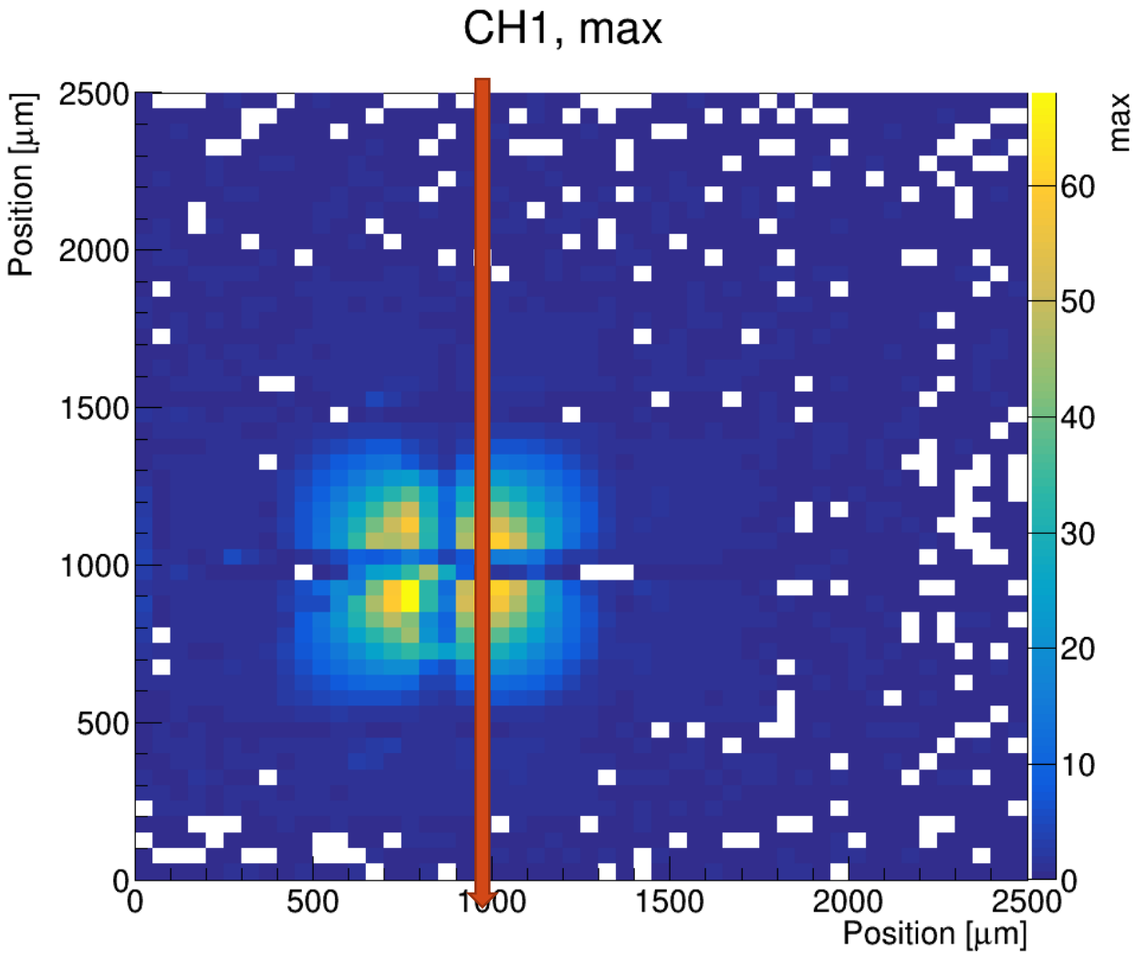
FBK RSD1 etched preliminary results (fractions)

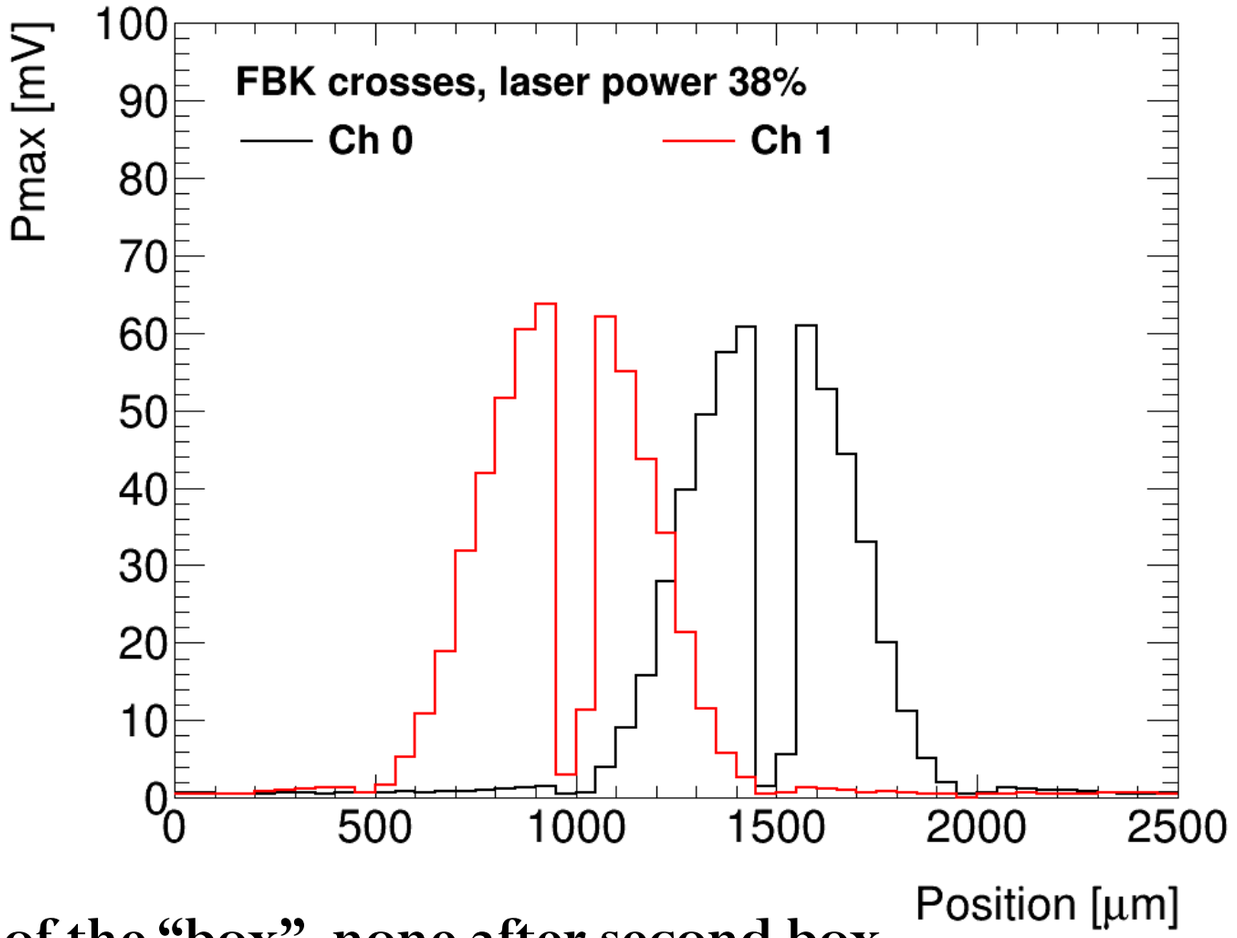




Smooth variation in fractions from one cross to the next

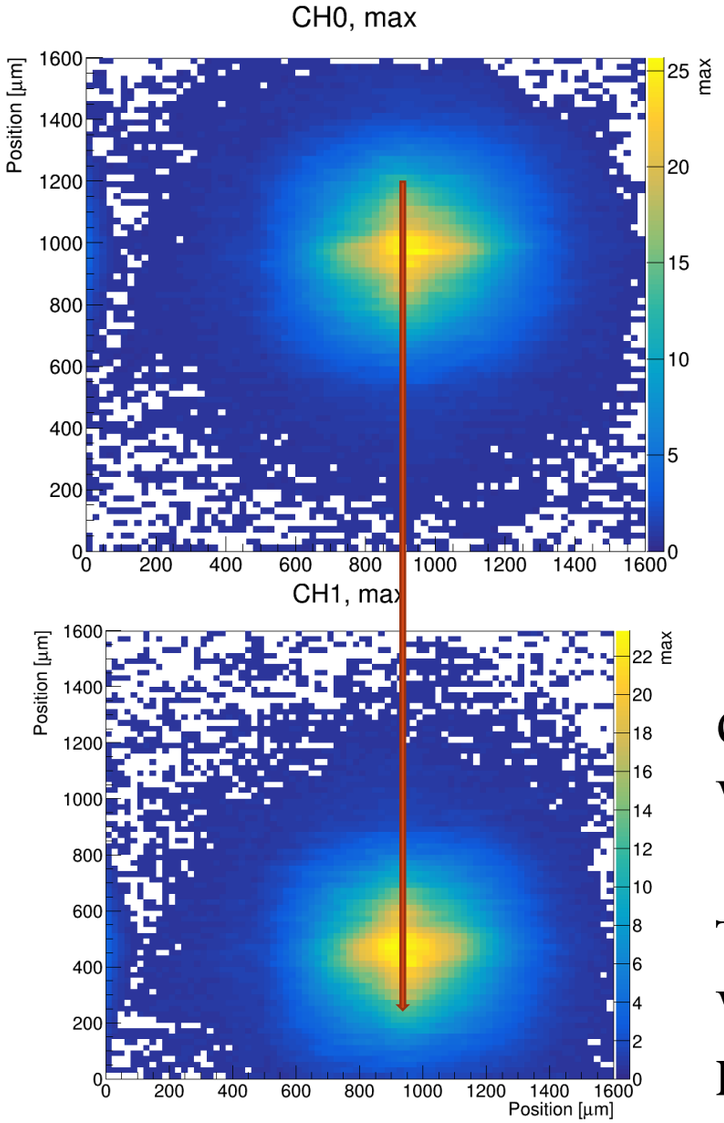
FBK RSD1 etched preliminary results (entire sensor)

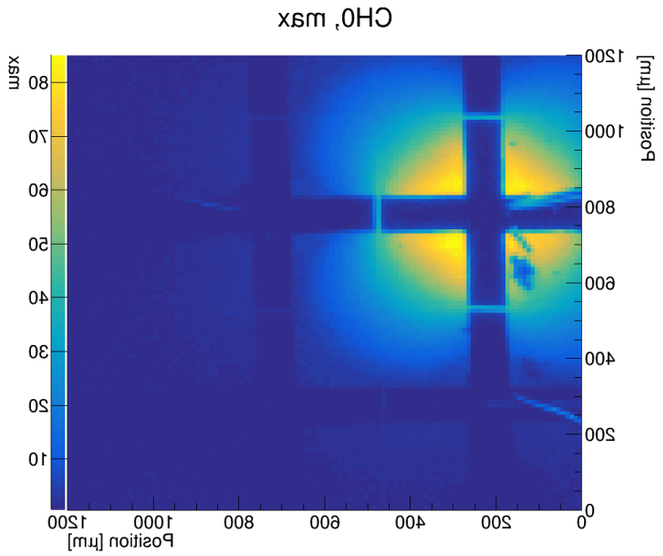




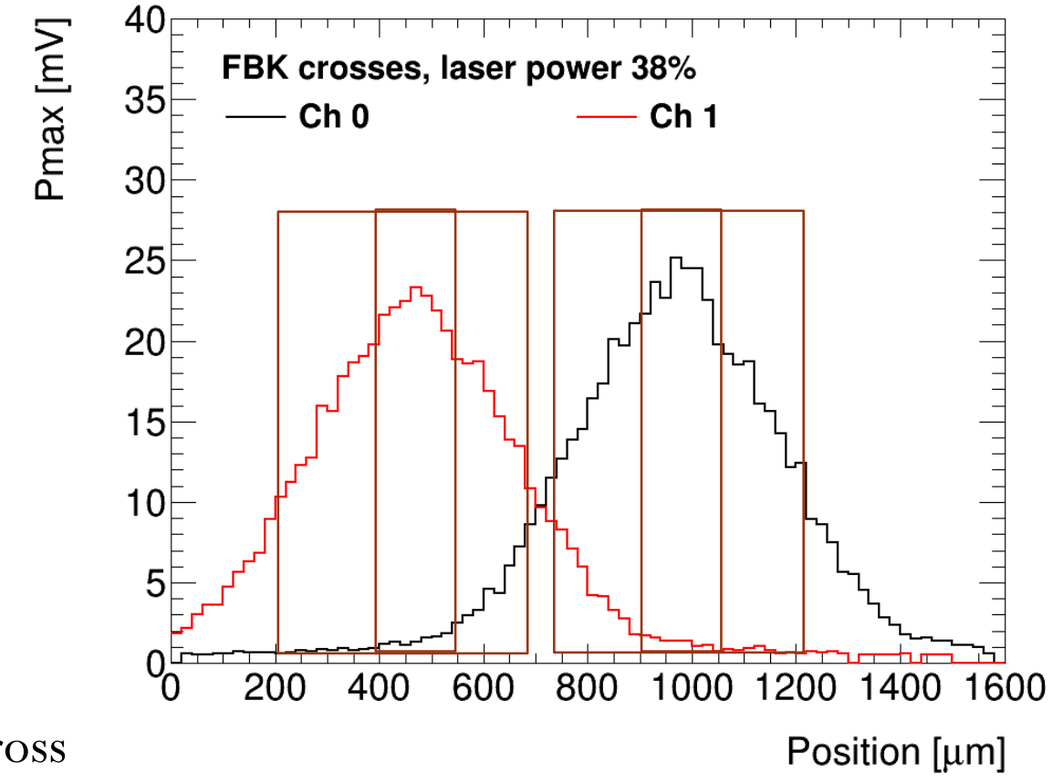
No long range signal, small signal outside of the "box", none after second box

FBK RSD1 etched preliminary results (backside)





(flipped)



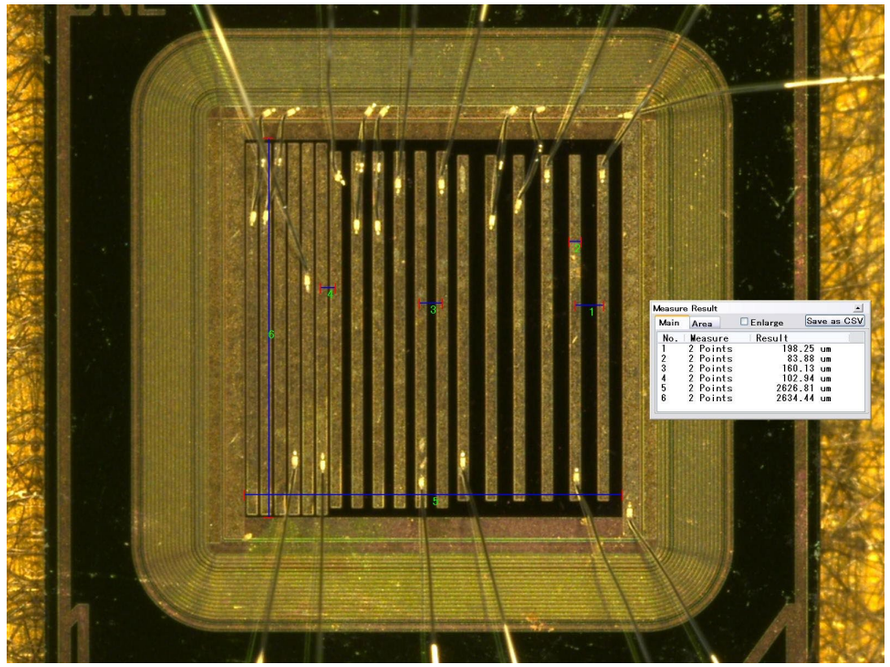
Cross structure is roughly seen
With backside scanning

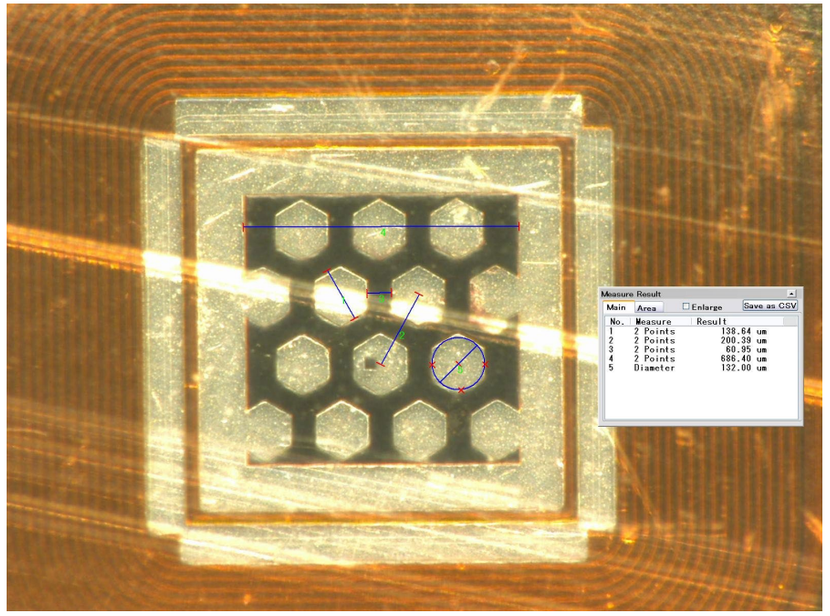
There's signal variation under the cross
With good signal from neighbor until the center area
Possible to reconstruct signal under the metal (at least in the "arm")

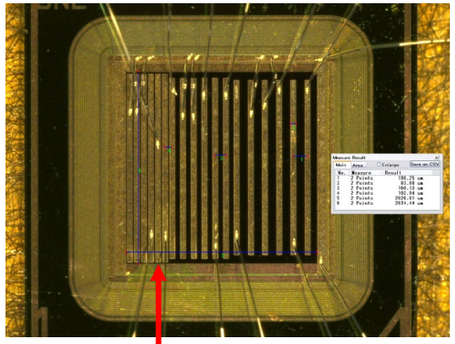
BNL AC-LGAD testing

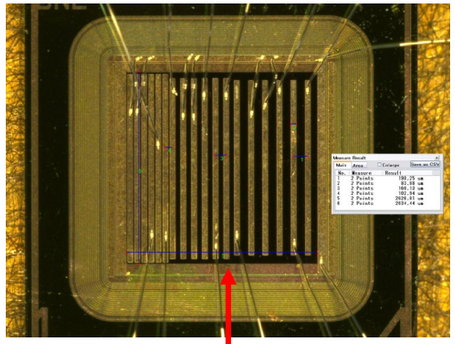
BNL AC-LGAD geometries

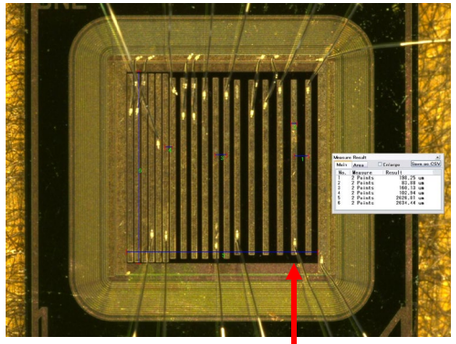
- BNL AC-LGADs laser studies at UCSC
- Sensors under study: strips and hexagons
- Strips with different pitches:
  - 80um strip width
  - 200um, 150um, 100um pitch
- Hexagons:
  - 200um pitch
  - 130um hexagon diameter
- Sensors etched on the backside at BNL to allow backside illumination

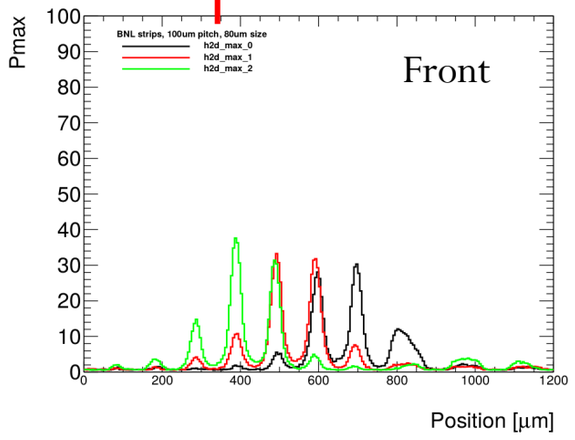


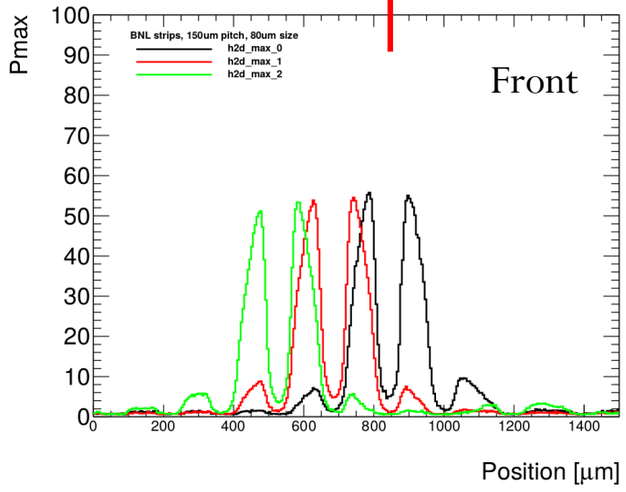


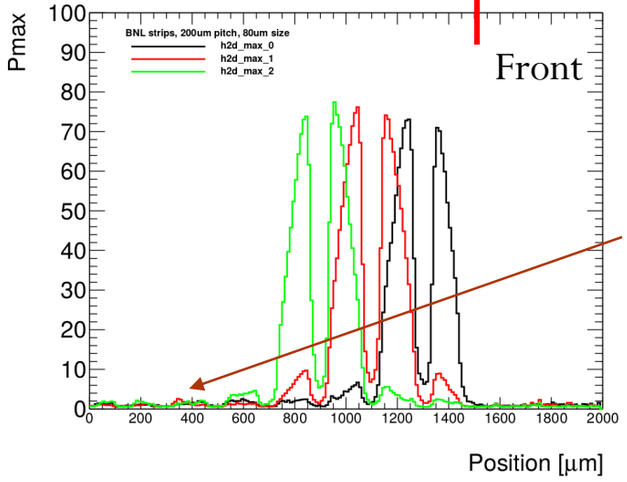


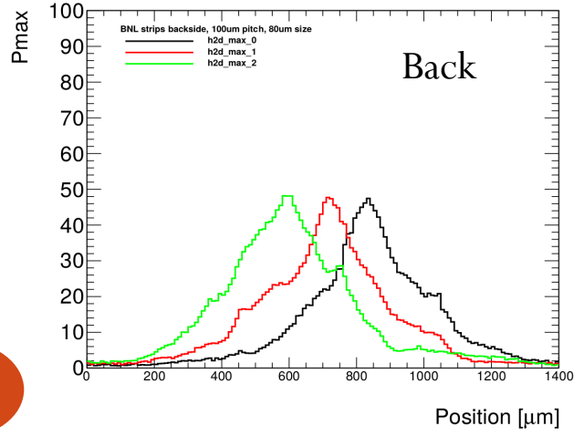


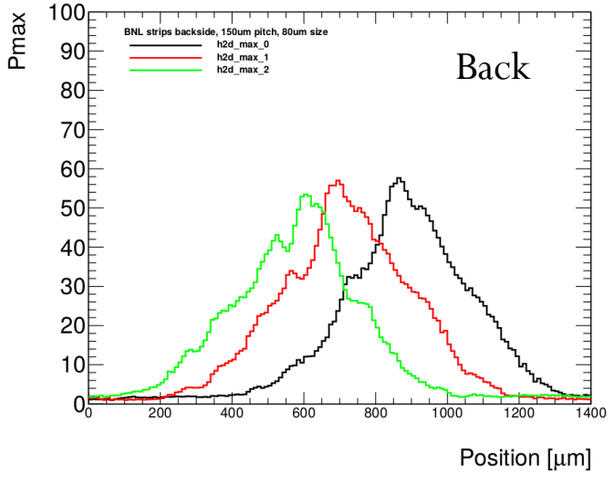


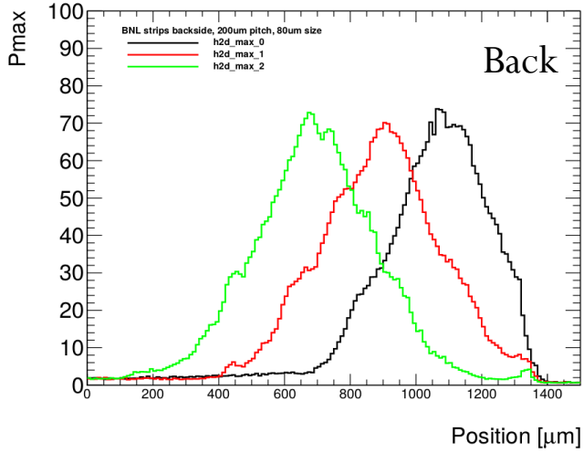






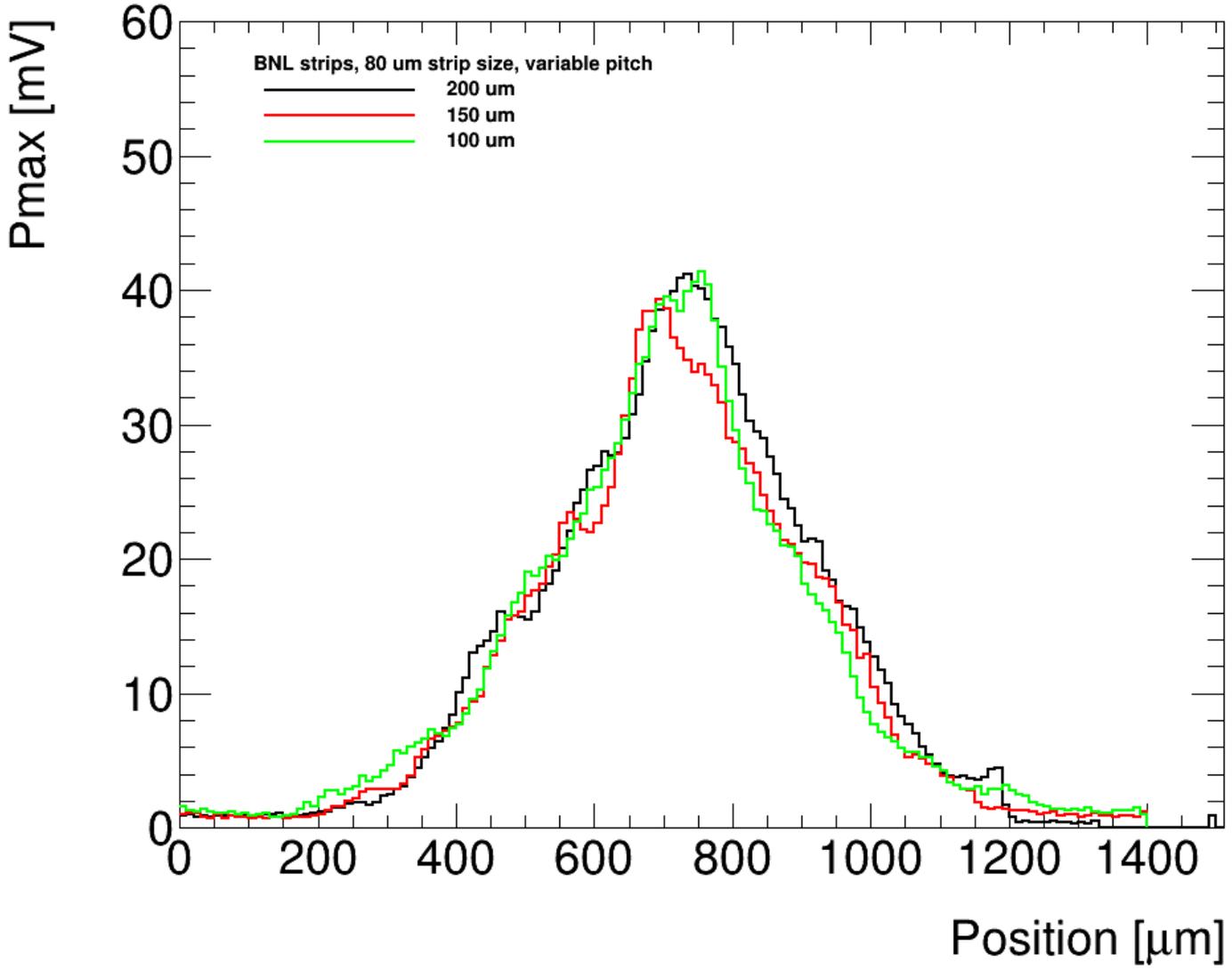




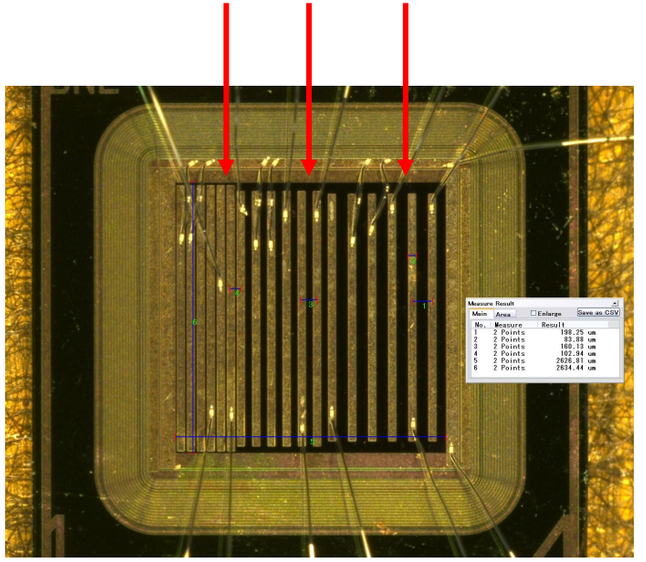


BNL AC-LGAD strips

There's a 2-5% long range
Contribution to be understood



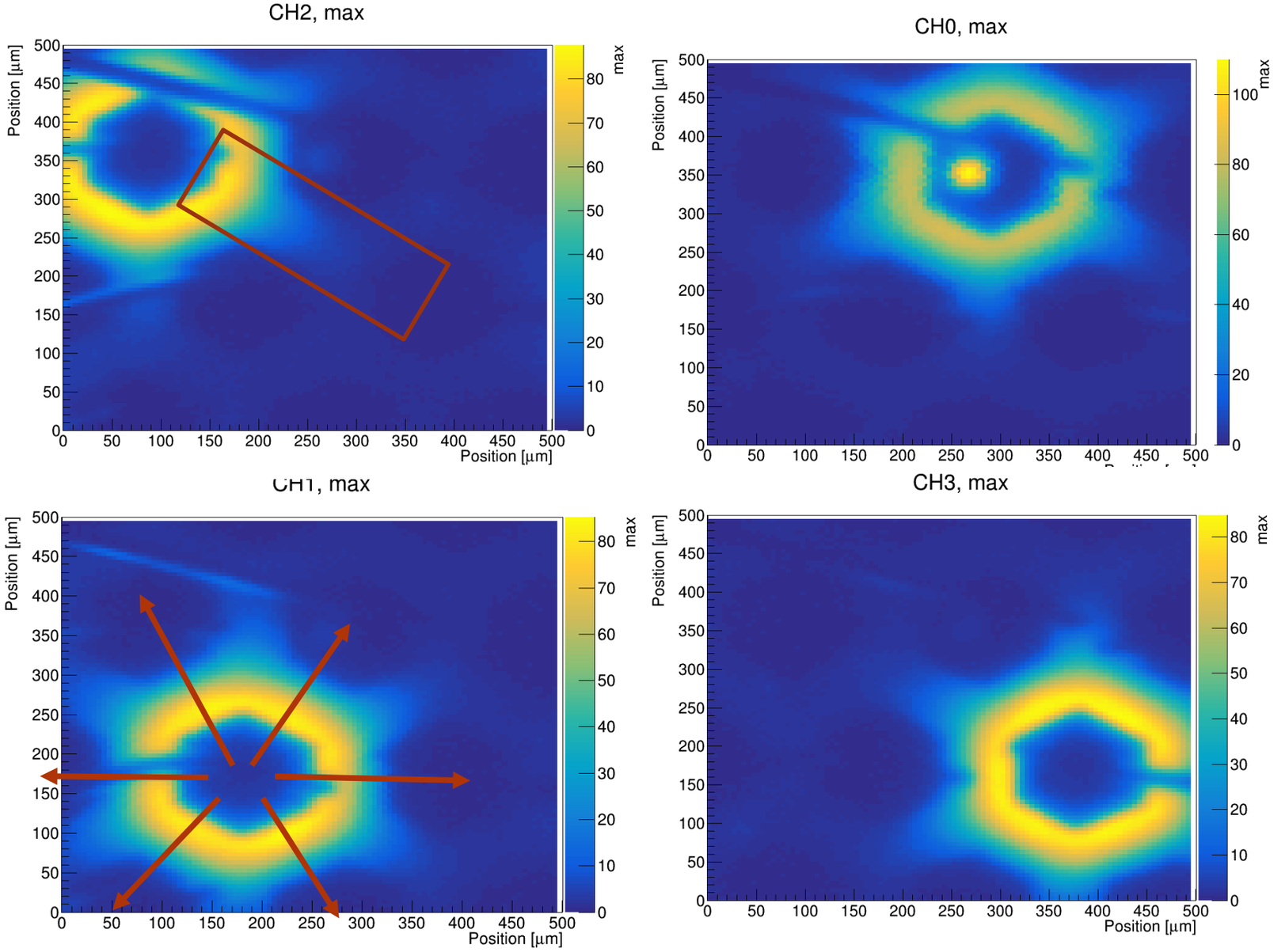
- Backside response of strips with three different pitches
- Same Pmax profile
  - Seems independent from the pitch
- It should depend on strip width



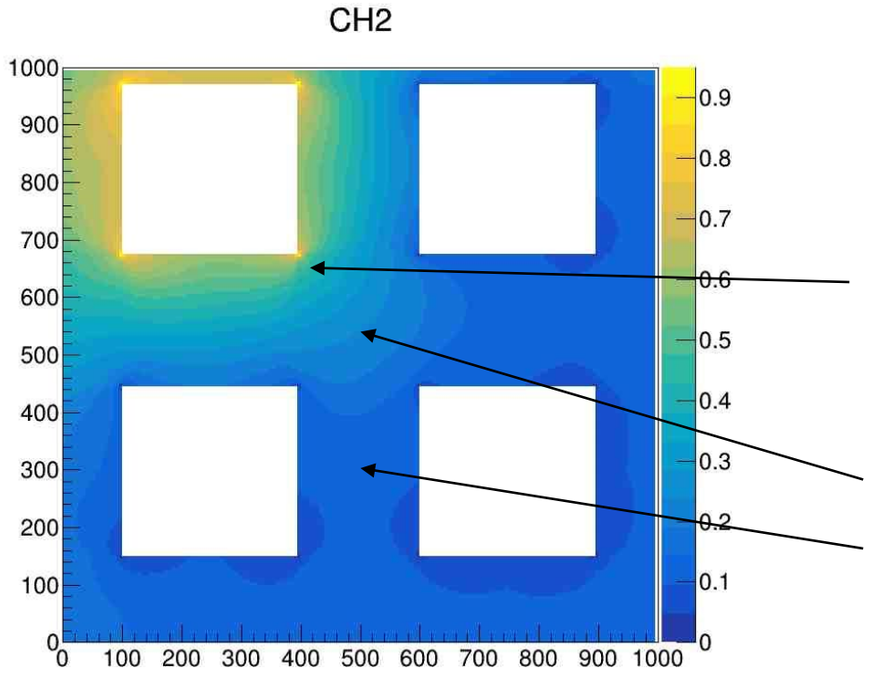
BNL Hexagons

For master formula method see: https://arxiv.org/abs/2007.09528

- Read out 4 hexagons
- Use master formula for position reconstruction
- Elementary "box" that needs 4ch for reconstruction in between
  - Ideally reconstruction also work under the metal using all 6 neighbors
- Hexagons are approximated to circles in master formula

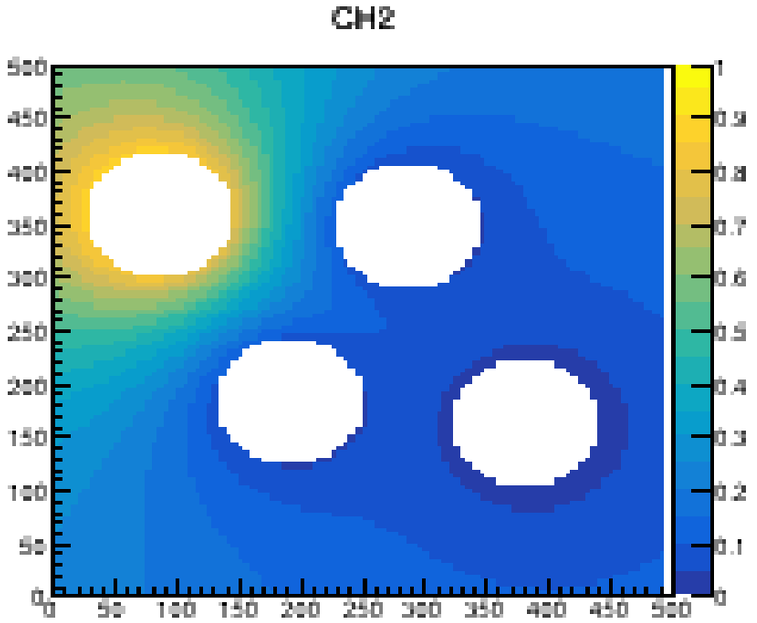


Master formula fraction calculation



With square pads there are troublesome spots in the master formula

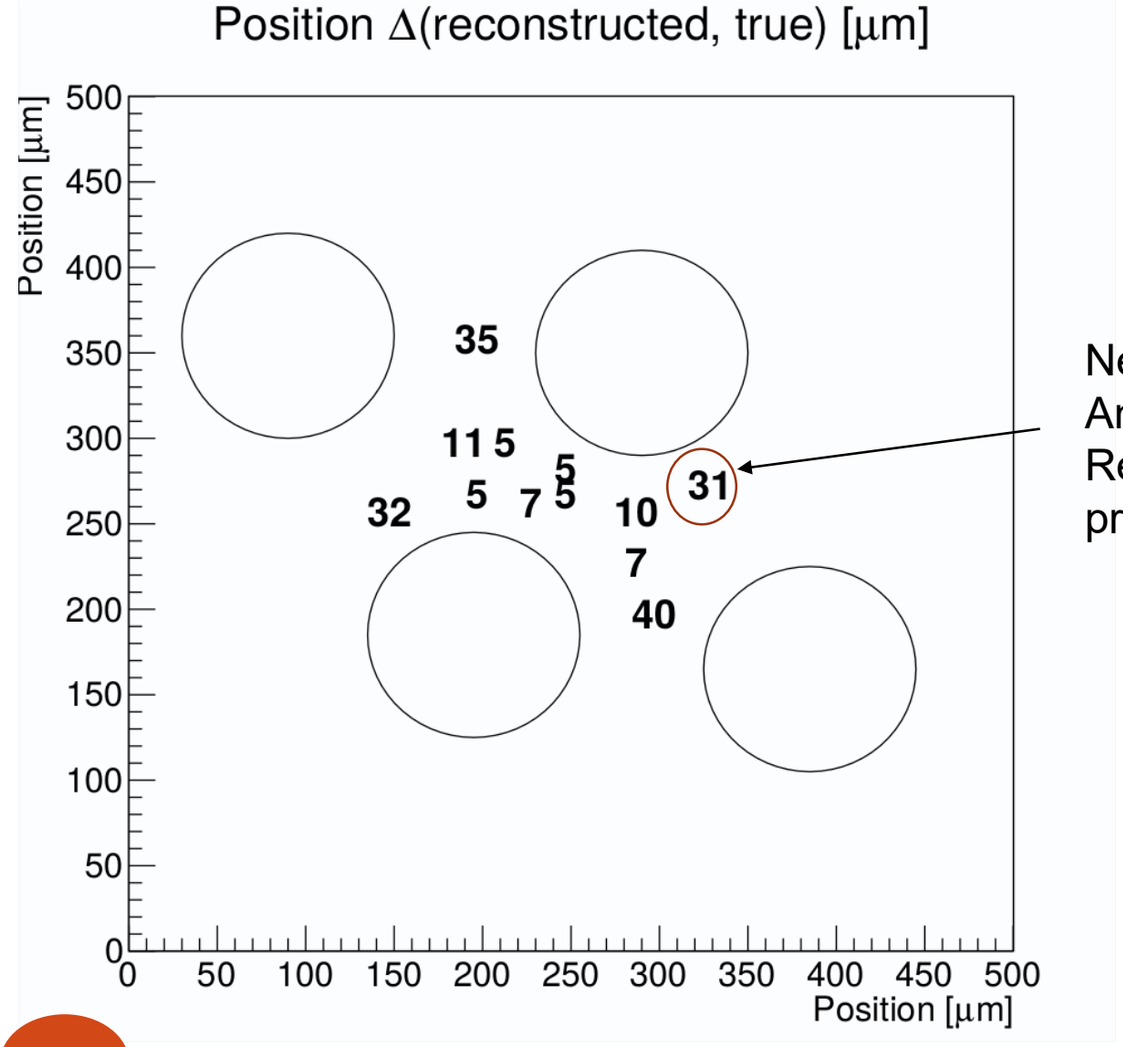
Also different “regions” in between pads that require a different number of pads to reconstruct e.g.
4 channels
6 channels



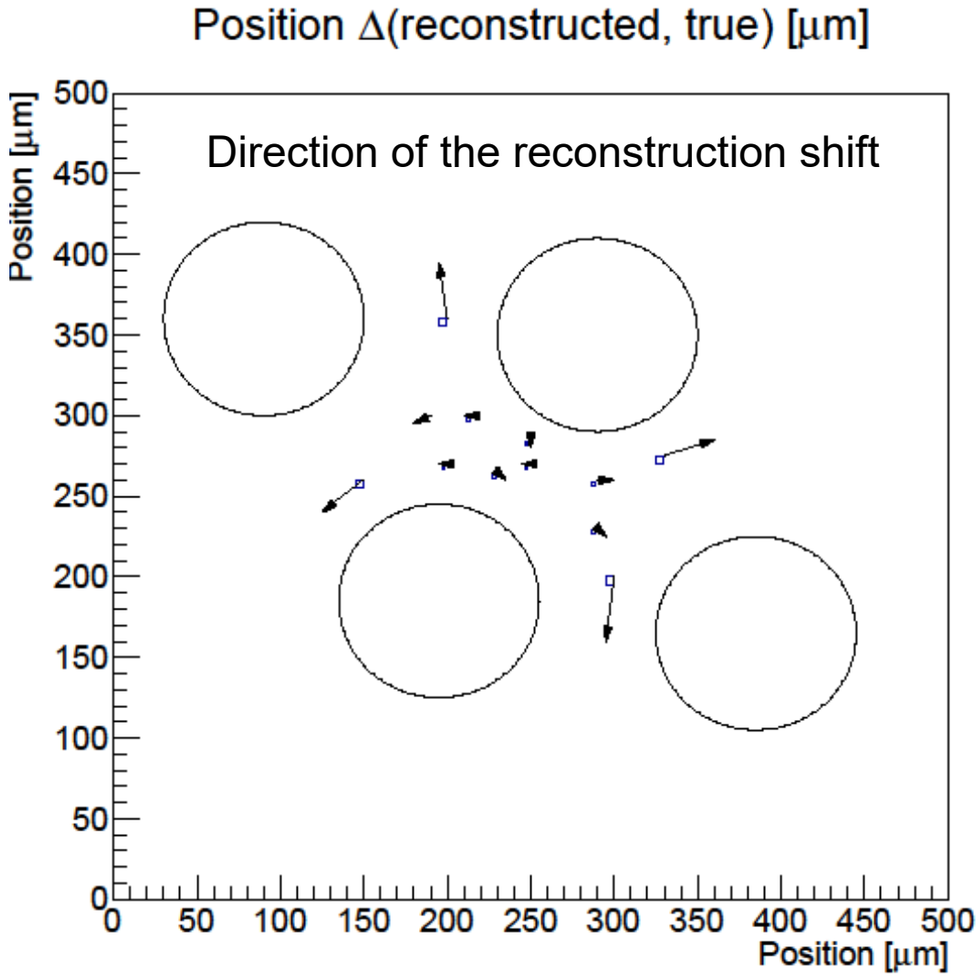
Hexagons are approximated with circles
with circles the master formula is very smooth
With staggered configuration the reconstruction should be more homogeneous

Note: master formula is not the most efficient algorithm, see Slides from Filippo on ML reconstruction next!

Position (reco-true) is <10um in central region (not resolution)

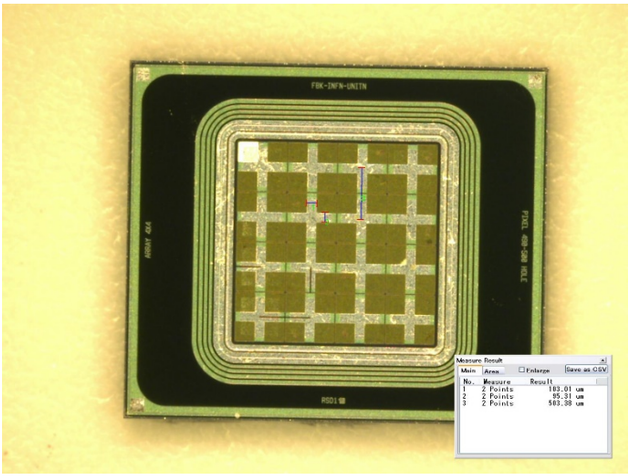


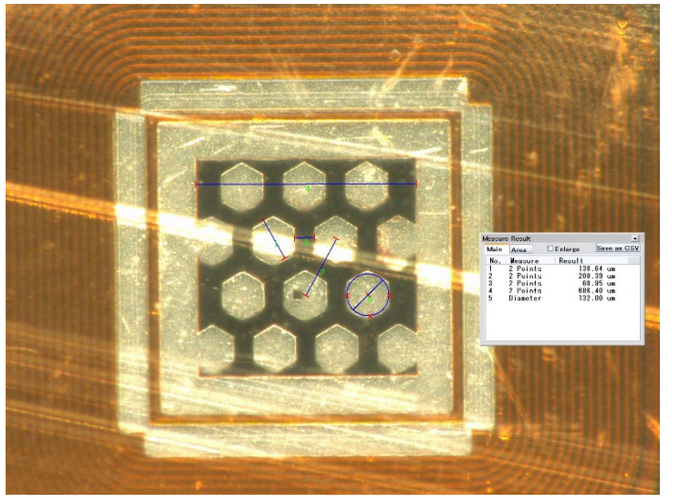
Need info from Another pad to Reconstruct properly



Conclusions

- It is possible to create new AC-LGAD pad design by modifying existing sensors
  - Procedure is time consuming but if foreseen at production level might be faster
  - Idea: produce fully metalized general purpose sensors to be etched for the prototype application
- Results from crosses design are very promising
  - Signal is mostly contained in "boxes" and reconstruction is streamlined
  - Reconstruction under cross is possible
  - Improving the design: cross with 100x100 bonding pad in the middle and very thin arms
- Other geometries to be tested soon





- AC-LGAD strips
  - Pmax profile does not seem to be dependent on the strip pitch
  - Long range effect to be understood (cross-talk with neighbors or N+?)
- AC-LGAD hexagons
  - Improved design to have better reconstruction outside and inside metal using all neighbors

Many thanks to the SCIPP group students and technicians!

Thanks to the FBK team for producing and providing the sensors for this study

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Backup